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PRETEST REPORT FOR THE 0.105-SCALE APOLLO
CANARD STATIC FORCE MODEL (FS-2) IN THE
AMES 11- BY 11-FOOT, 9- BY 7-FOOT, AND
8- BY 7-FOOT UNITARY PLAN WIND TUNNELS
(AMES VIII)

5 May 1964

CONTRACT NAS9-150

(SID-64936) PRETEST REPORT FOR THE
0.105-SCALE APOLLO CANARD STATIC FORCE MODEL
(FS-2) IN THE AMES 11- BY 11-FOOT, 9- BY
7-FOOT, AND 8- BY 7-FOOT UNITARY PLAN WIND
TUNNELS (AMES 8) (North American Aviation, 00/02

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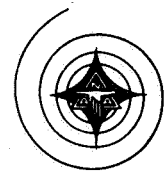
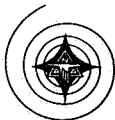


Exhibit I, Paragraph 5.5

NORTH AMERICAN AVIATION, INC.
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FOREWORD

This report was prepared under NASA Apollo contract NAS9-150, Paragraph 5.5, Exhibit I, by B.W. Cameron, Jr., of Experimental Aerodynamics, Systems Dynamics, Space and Information Systems Division, North American Aviation, Incorporated.



ABSTRACT

This report pertains to the test of a 0.105-scale static force (FS-2) model of the Apollo post-abort canard configuration in the Ames Unitary Plan Wind Tunnel, covering a Mach number range from $M = 0.7$ to 3.4. The purpose of these tests is to determine the aerodynamic characteristics of the post-abort canard configuration and the escape rocket with canard deployed.



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INTRODUCTION

This report presents test and model information pertaining to the tests of the 0.105-scale Apollo FS-2 model in the Ames 11- by 11-foot, 9- by 7-foot, and 8- by 7-foot unitary plan wind tunnels. The tests are scheduled to be conducted from 1 June through 26 June 1964.

The purpose of this test is to obtain the aerodynamic static stability characteristics of an Apollo post-abort canard configuration and the canard rocket motor, with a multiple balance installation. The test program calls for a Mach number range of 0.7 through 3.4 over a 360-degree angle-of-attack range, with the canards at roll angles of 0, 30, and 60 degrees.

In accordance with present security requirements, all wind tunnel data will be classified CONFIDENTIAL. The model, model drawings, and model photographs will be unclassified.



I. MODEL DESCRIPTION

MODEL CONSTRUCTION

The 0.105-scale Apollo FS-2 model has been updated to represent the latest post-abort canard configuration.

DUAL BALANCE MODEL

The escape motor has been modified to accept a Task Mark II T 1.5 balance (Figure 1). The balance is supported on the forward end of the tower; the lower end of the tower is attached to the balance block. With this arrangement the Task Mark XVI T 2.5 balance measures the total post-abort canard configuration loads, while the Task Mark II T 1.5 balance provides load for the rocket motor with canards deployed. The Task Mark XVI T 2.5 balance is installed in the normal manner in the $\theta = 0^\circ$, 40° , 80° , 120° , and 140° -degree balance cavities.

HEAT SHIELD FORWARD BALANCE MODEL

Because of the problems of testing the post-abort canard configuration in the heat shield forward attitude, a new rocket motor was designed and fabricated to accept the Task Mark XVI T 2.5 balance (Figure 2). On this model the tower and command module are supported upstream, in front of the balance. This method of testing affords relatively sting-free interference data for the 180° -degree angle-of-attack region.

FULL-SCALE DIMENSION AND NOMENCLATURE

The full-scale dimensions and the model nomenclature are listed below and illustrated in Figures 3 and 4.

Command Module, C43, (Figures 5 and 6)

Maximum diameter	154.0 inches
Radius of spherical heat shield	184.8 inches
Corner radius	7.7 inches
Afterbody semivertex angle	33.0 degrees
Afterbody vertex radius	9.152 inches
Scimitar antenna (2)	
Umbilical fairing	

Vent, V₅ (Figure 7)

Overall length	17.48 inches
Height	2.67 inches

Tower Structure, T₃₂ (Figure 8)

Total length	113.135 inches
Number of longitudinal members	4
Diameter of longitudinal members	4.105 inches
Diameter of cross braces	2.867 inches
Distances between attachment points at command module	46.762 inches

Escape Motor, E₇₁ (Figure 8)

Total length	286.487 inches
Diameter of escape rocket	26.0 inches
Diameter of escape rocket base	52.733 inches
Skirt flare angle	34.0 degrees
Nose radius	2.0 inches
Nose included angle	30.0 degrees
Canard surfaces	

Escape Motor, E₇₂ (Figure 9)

Total length	243.8 inches
Diameter of escape rocket	28.85 inches
Diameter of escape rocket base	52.733 inches
Skirt flare angle	34.0 degrees
Canard surfaces	

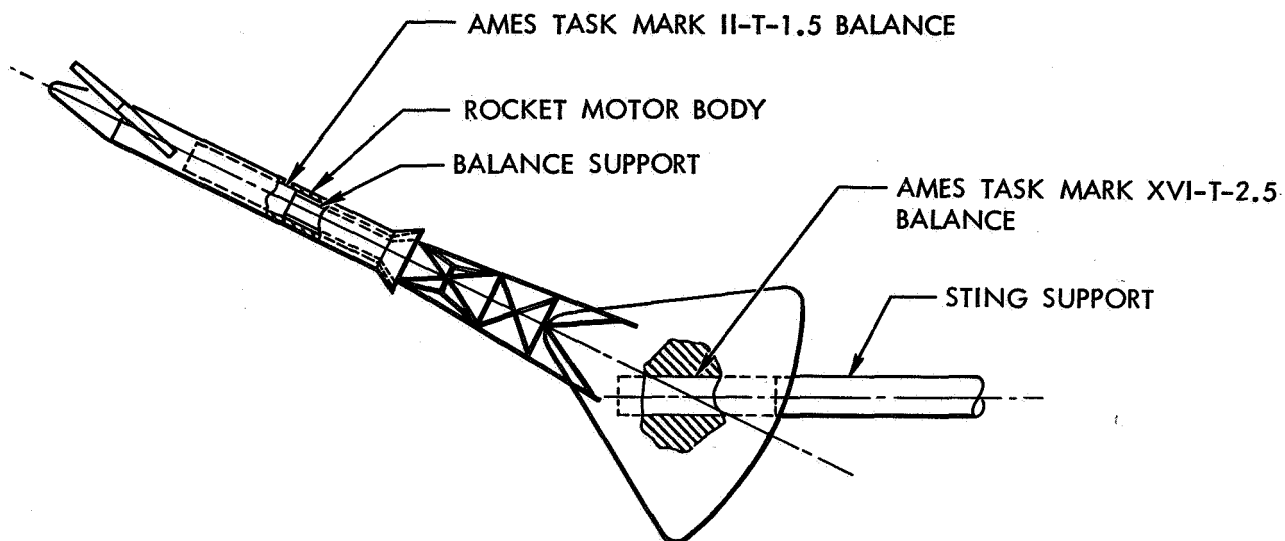


Figure 1. Dual Balance Model

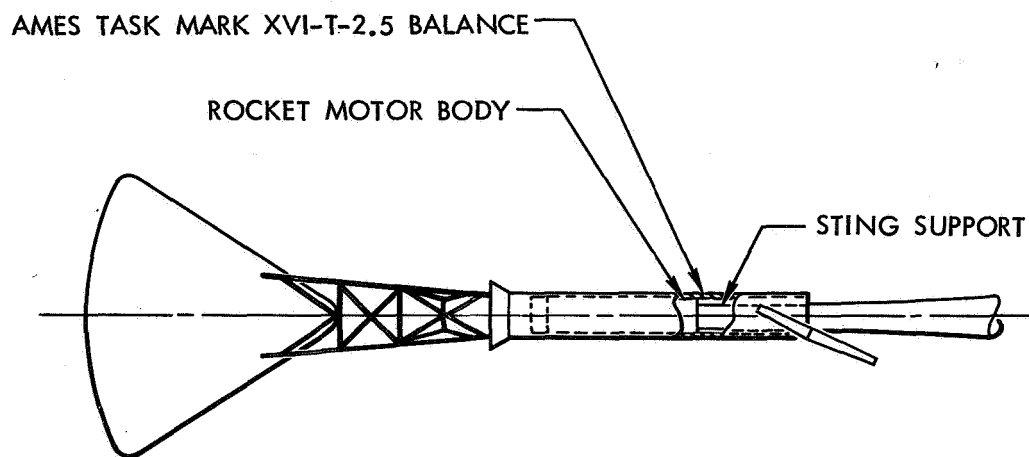
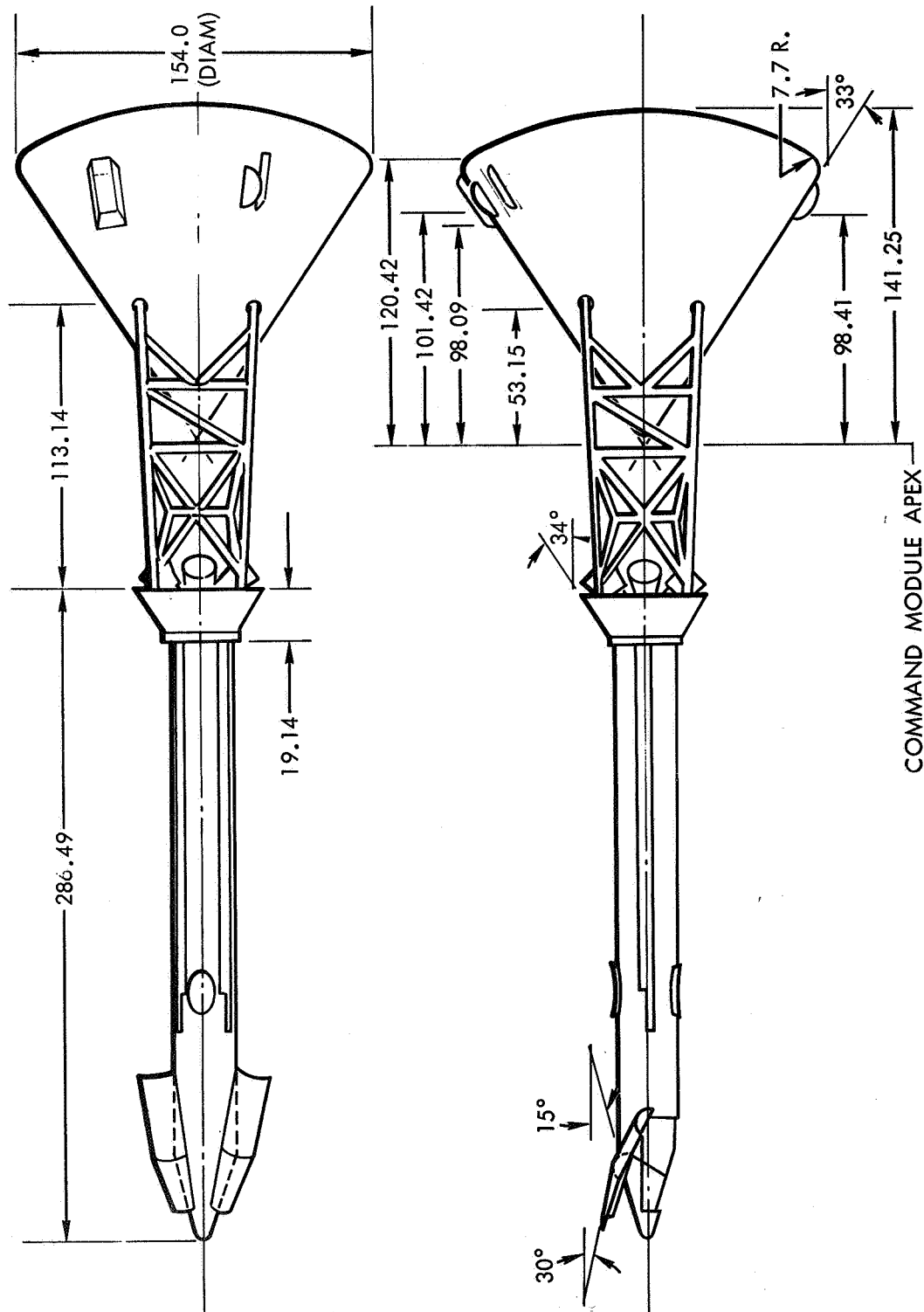


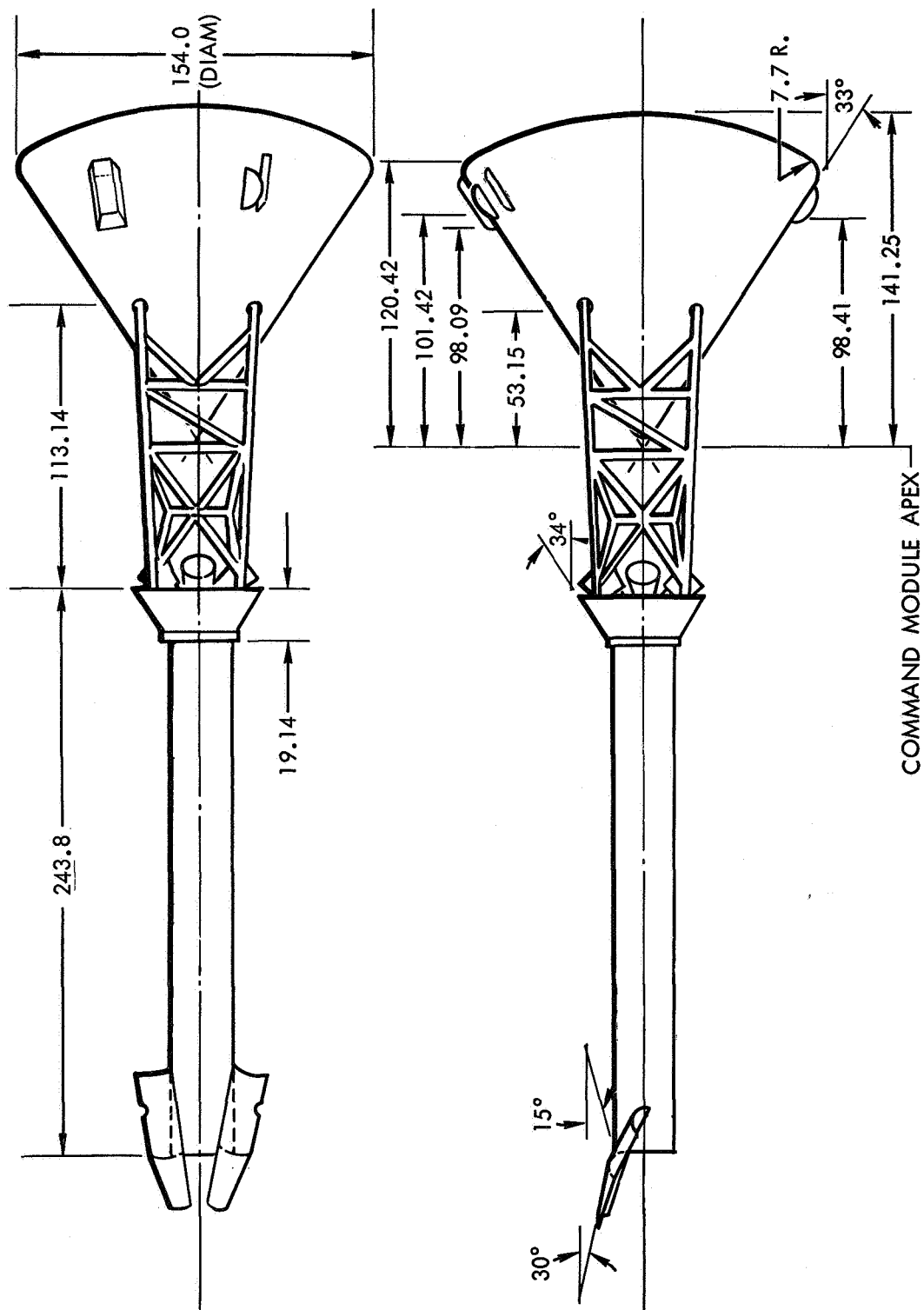
Figure 2. Heat Shield Forward Balance Model



FULL-SCALE DIMENSIONS IN INCHES

DRAWING NOT TO SCALE

Figure 3. Post-Abort Canard Configuration, C₄₃ V₅ T₃₂ E₇₁

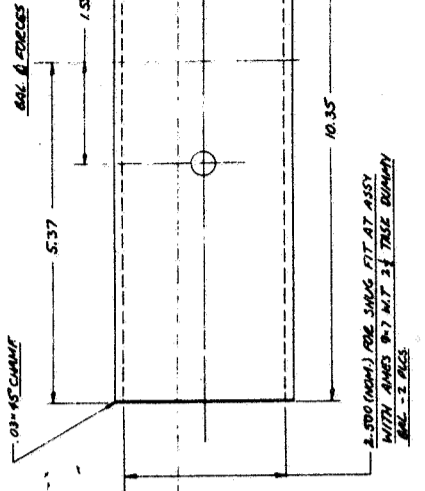
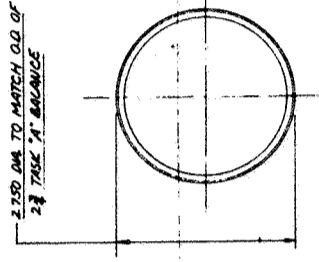


DRAWING NOT TO SCALE

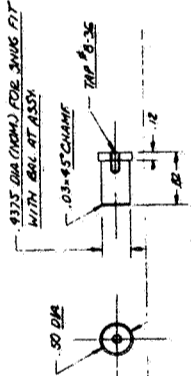
FULL-SCALE DIMENSIONS IN INCHES

Figure 4. Post-Abort Canard Configuration, C₄₃V₅T₃₂E₇₂

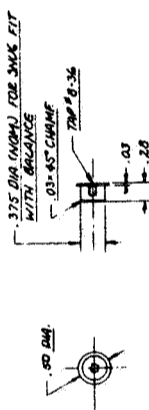
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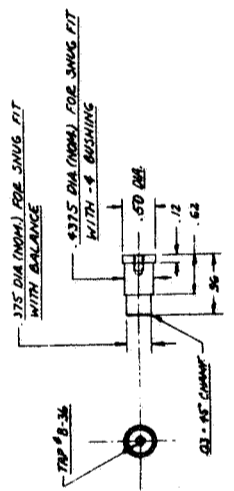
DETAIL (4) 2 1/2" AMES TASK BAL SLEEVE - 1 REQ
MATE - AMECO 17-4 PH ST 37L
H.T. - 180,000 - 210,000 PSI



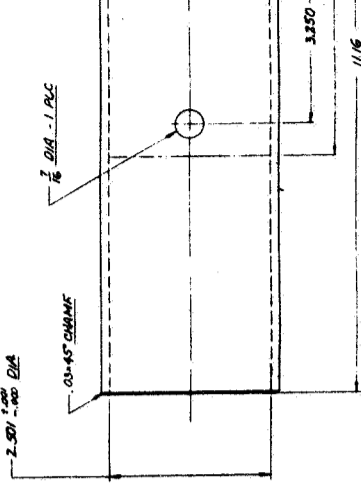
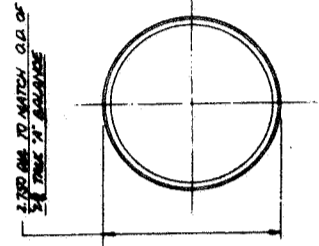
DETAIL (5) 2 1/2" TASK BAL PIN - 1 REQ
MATE - AMECO 17-4 PH ST 37L
H.T. - 180,000 - 210,000 PSI



DETAIL (6) AMES SLEEVE PIN - 1 REQ
MATE - AMECO 17-4 PH ST 37L
H.T. - 180,000 - 210,000 PSI



DETAIL (7) AMES BAL PIN - 1 REQ
MATE - AMECO 17-4 PH ST 37L
H.T. - 180,000 - 210,000 PSI



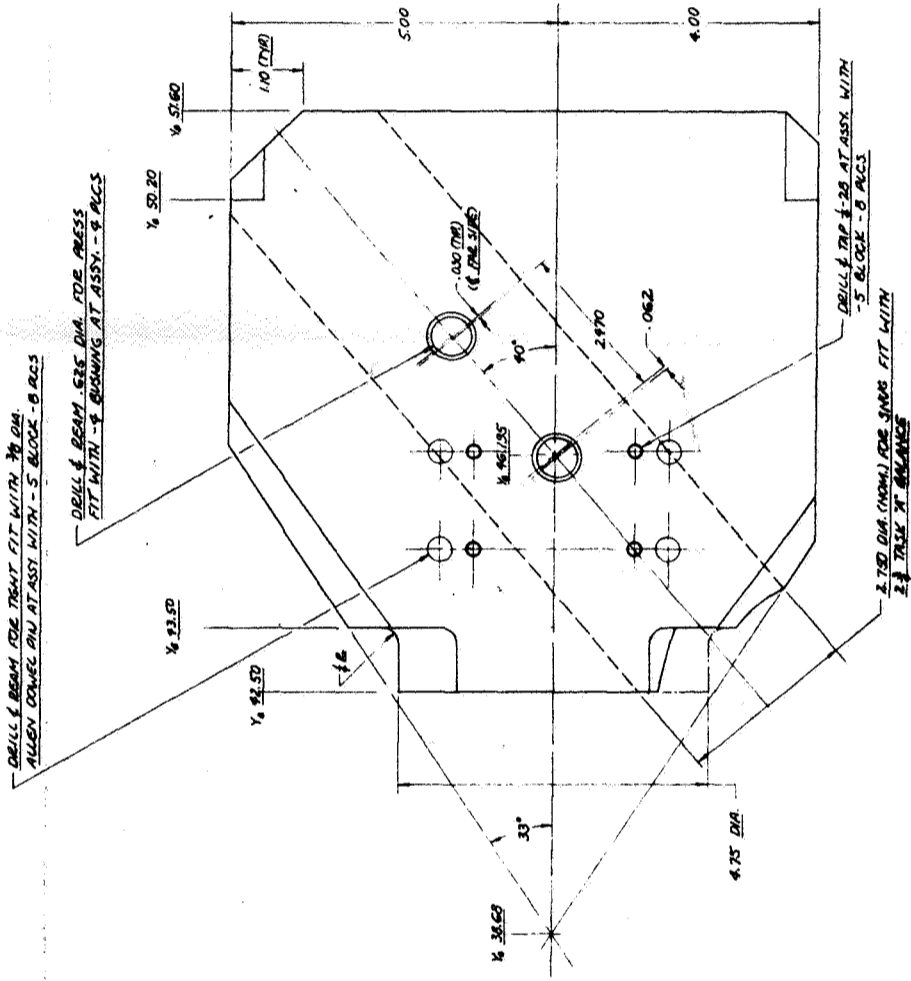
DETAIL (7) 2 1/2" A.E.D.C. TASK BAL SLEEVE - 1 REQ
MATE - AMECO 17-4 PH ST 37L
H.T. - 180,000 - 210,000 PSI

2.182

4.11000 TO
2.1.182

4.11000 TO
2.1.182

2.5700



DETAIL 3 BALANCE BLOCK - 1 PER
MIN - 1000 SZ OR EQUIV

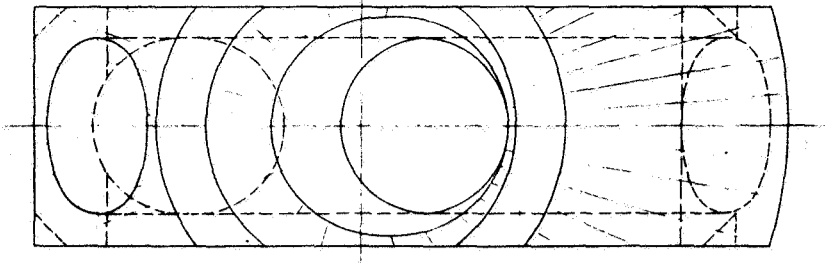
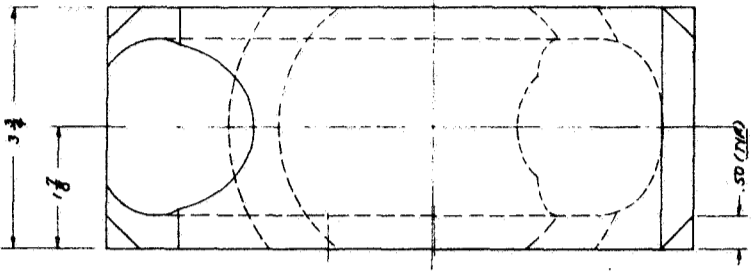
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10

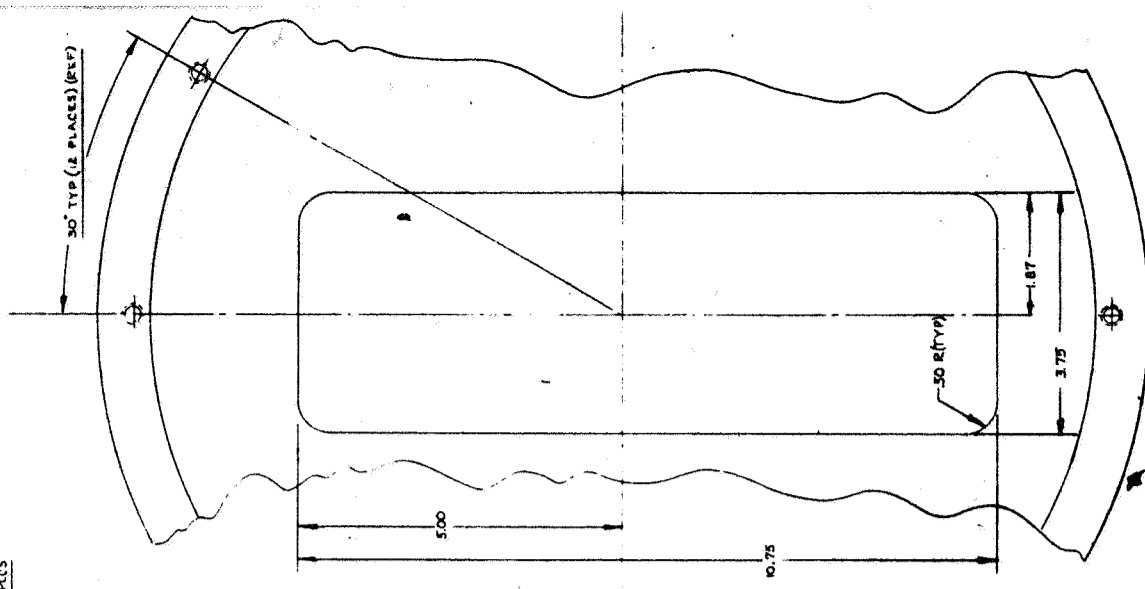
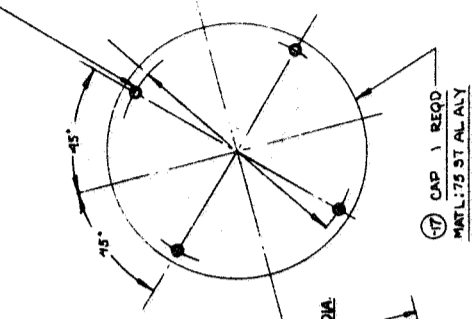
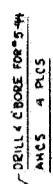
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8



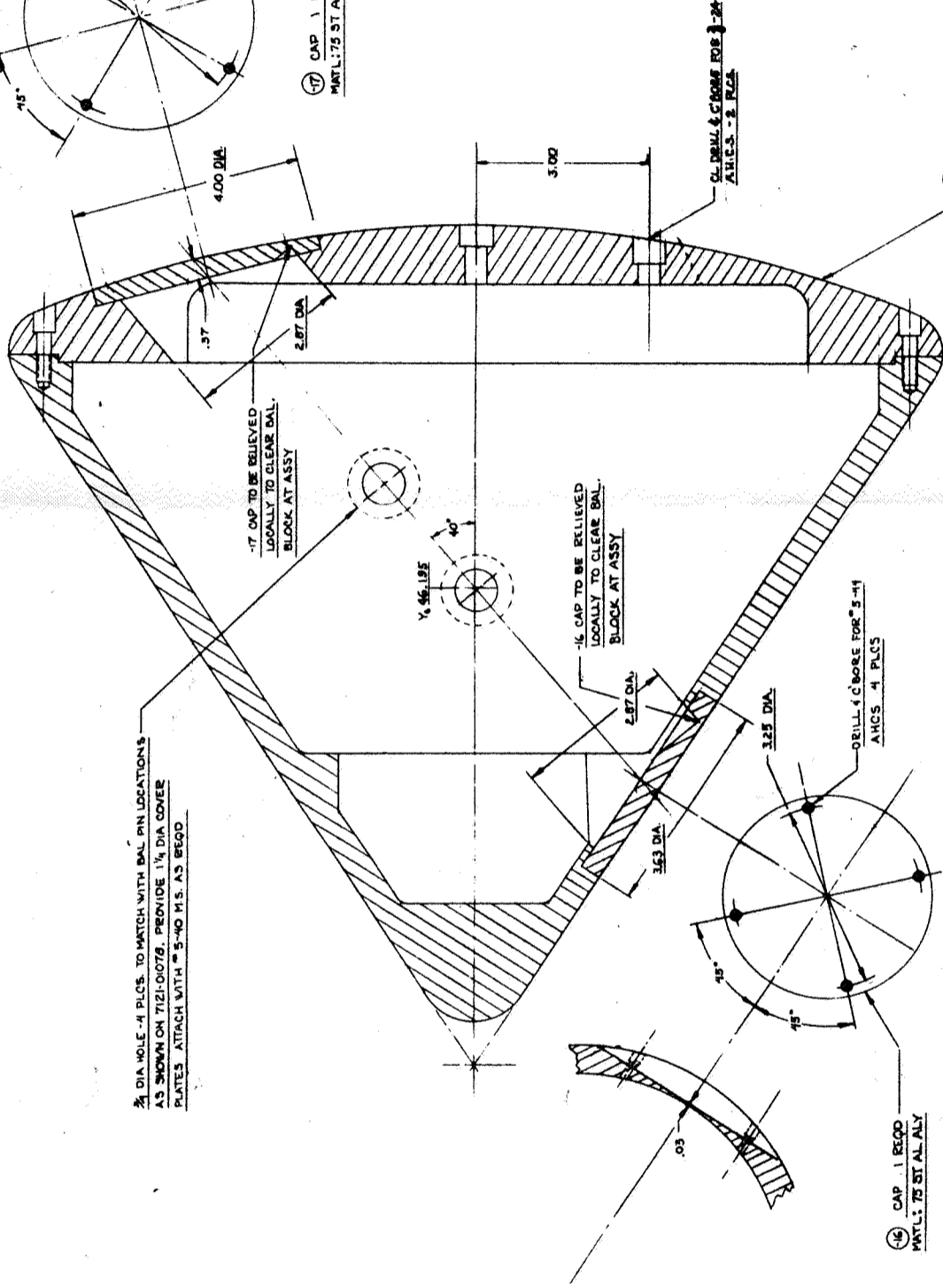
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- 2 -



DETAIL (-6) HEAT SHIELD 1 BEQD
PATL: 78 ST AL ALY

NOTE: -6 HEAT SHIELD IS IDENTICAL TO
-3 HEAT SHIELD EXCEPT AS NOTED



DETAIL (-4) COME 1 BIRD
MATERIAL: 75% AT ANY OF SEWAL
NOTE: -4 COME IS IDENTICAL TO
-7 COME EXCEPT AS NOTED

(-16) CAP 1 REQD -
MATL: 75 ST AL ALY

3/4 DIA HOLE - 4 PLCS. TO MATCH WITH BAL PIN LOCATIONS
AS SHOWN ON 7121-01078. PROVIDE 1 1/4 DIA COVER
PLATES ATTACH WITH 5-40 M.S. AS REQD

Fold-out #1



7121-01077

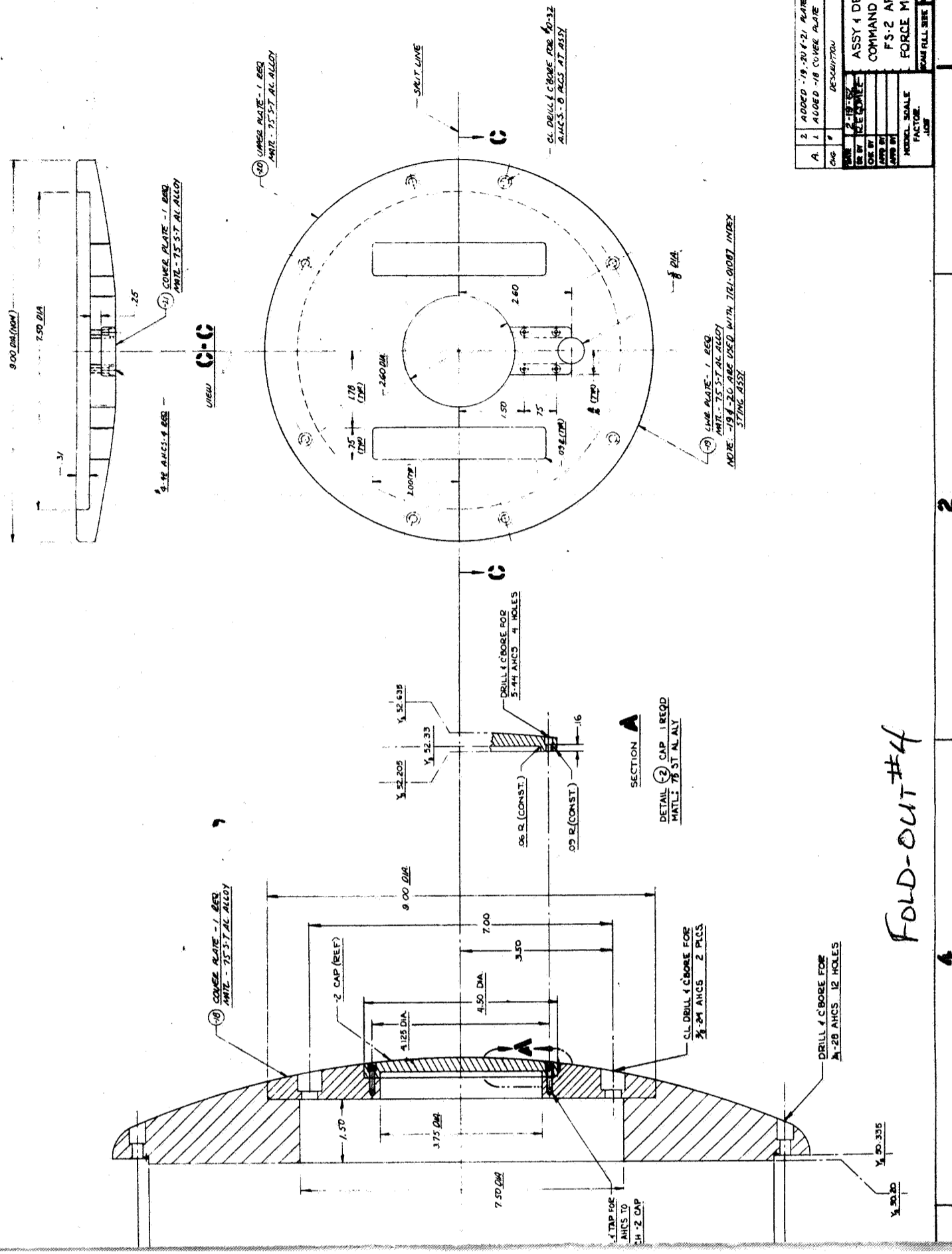
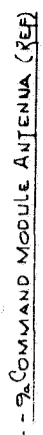
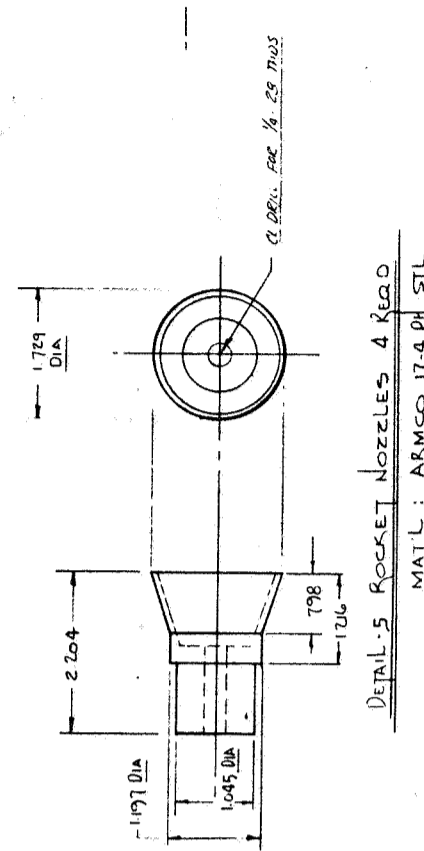
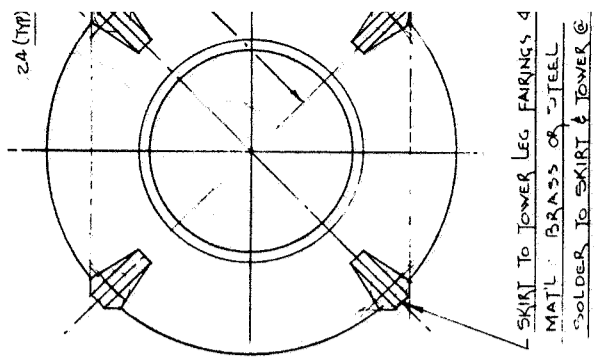


Figure 6. Assembly and Details - Command Module

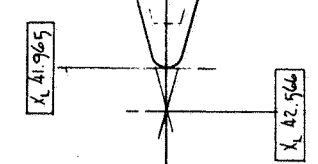
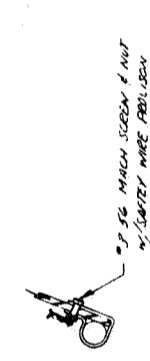




DETAIL - 5 ROCKET NOZZLES 4 REQ'D
MAT'L: ARMCO 17-4 PH STL

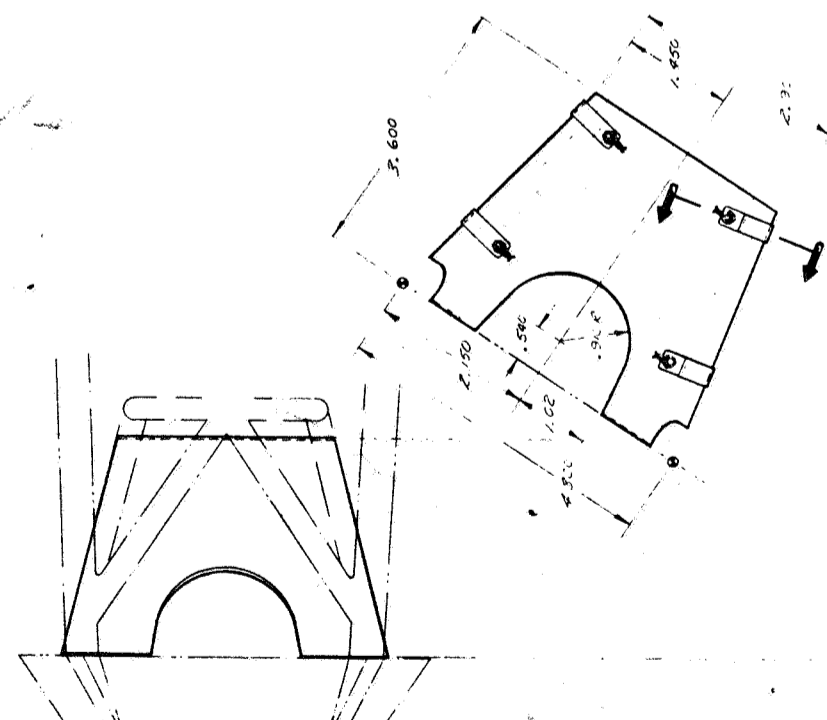


DETAIL - 6 NOZZLE NOZZLE 2 REQ'D
MAT'L: 4130 STEEL OR EQ. 11'



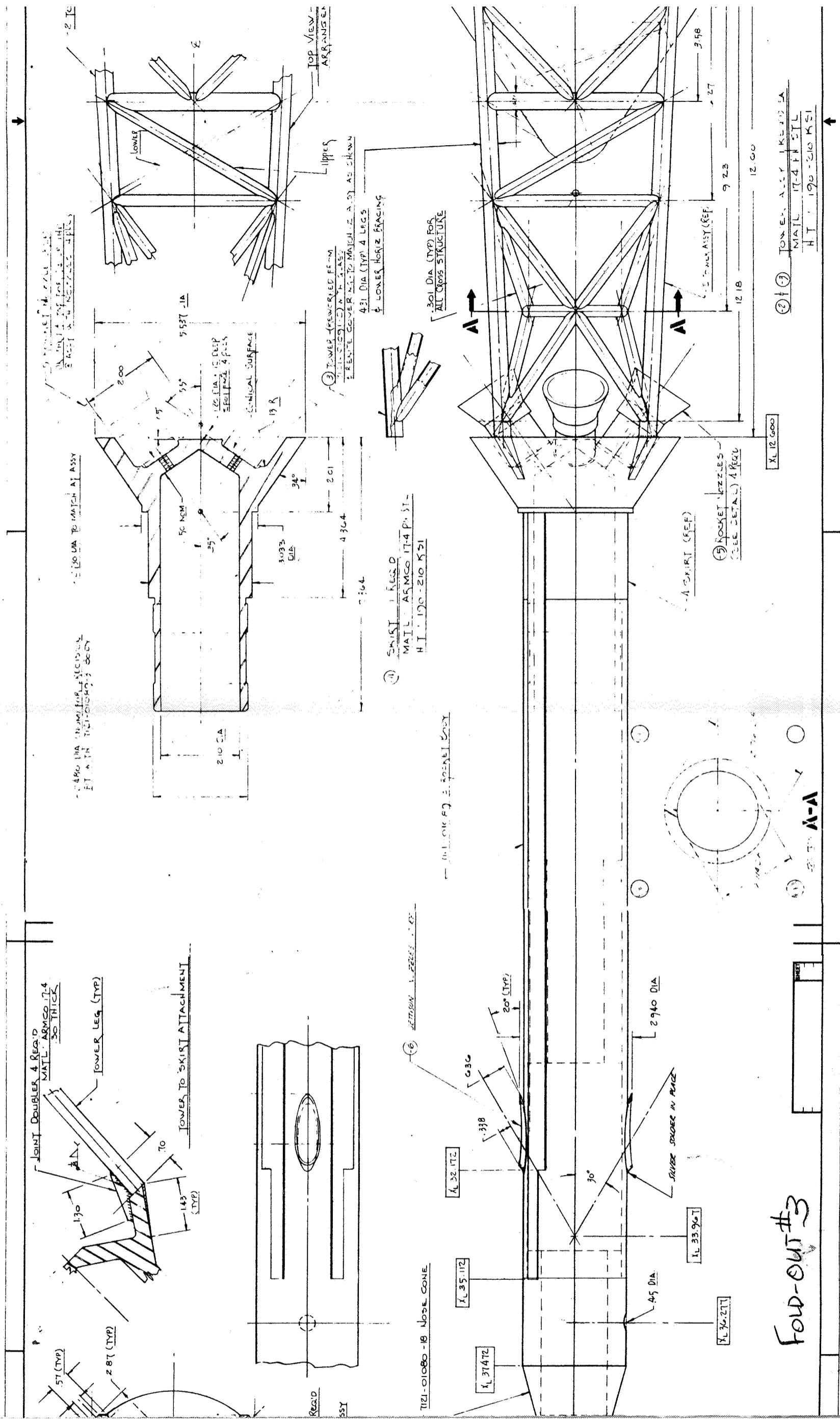
3-56 A.F.H. 5 2 REQ'D PER SET
LOCATE APPROX AS SHOWN W/ASSY

PLATES 2 SETS REQ'D
MAT'L: ARMCO 17-4 STL



DETAIL - 7 TOWER BASE 1 REQ'D
MAT'L: ST. STEEL

FOLD-OUT #2



FOLD-OUT #3

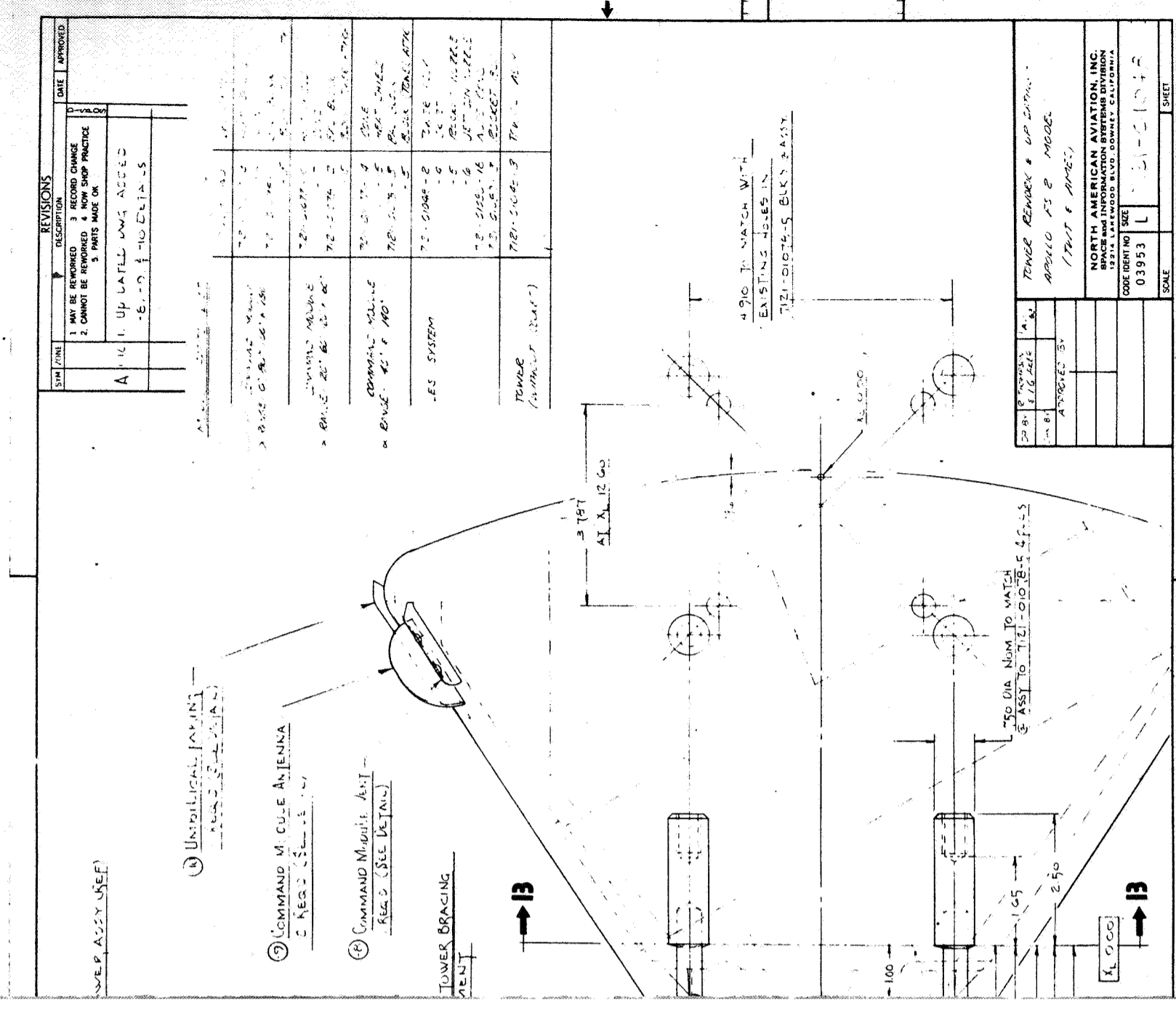
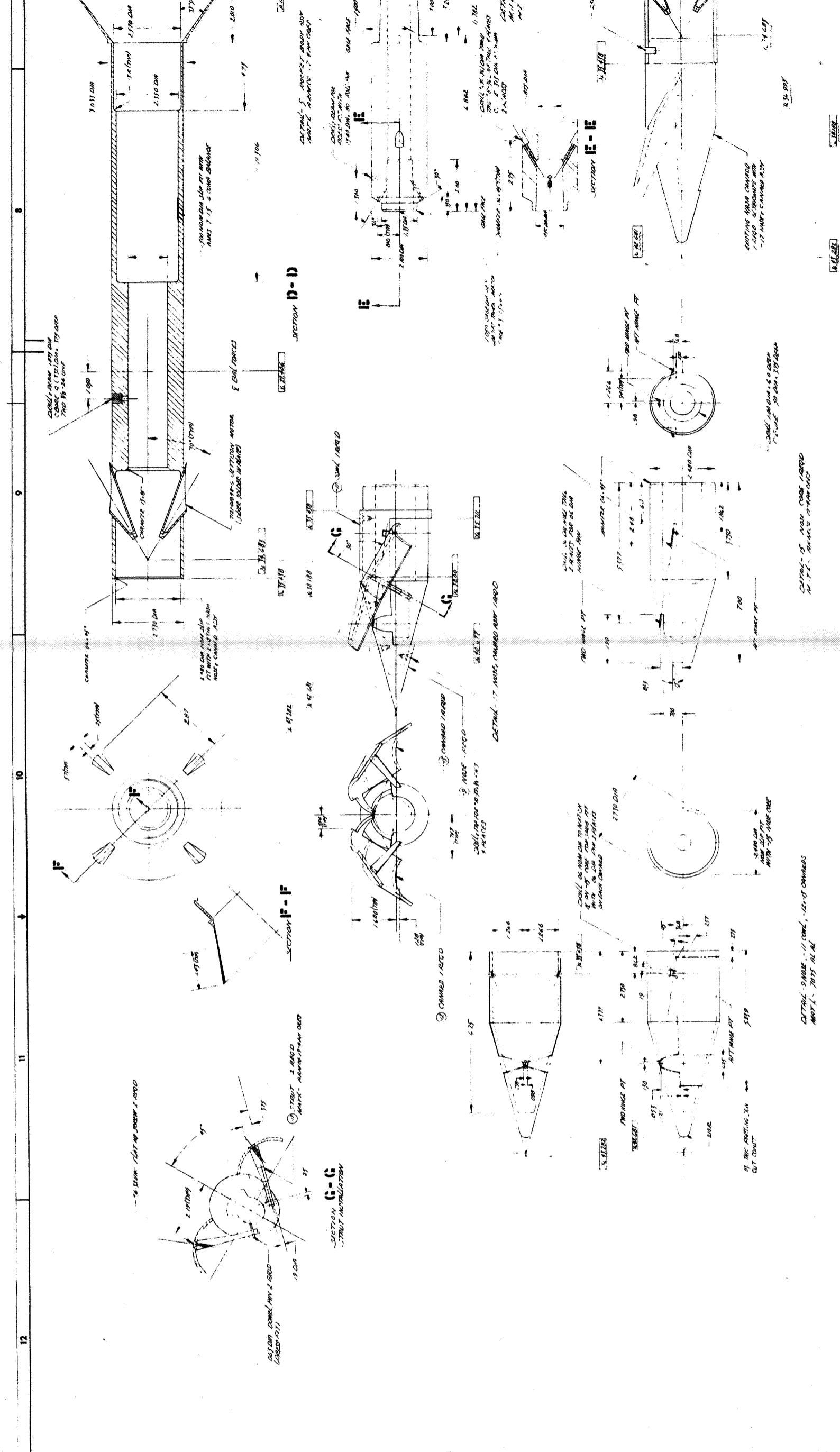


Figure 7. Model Assembly - Updated Revision Number 2

Figure 1
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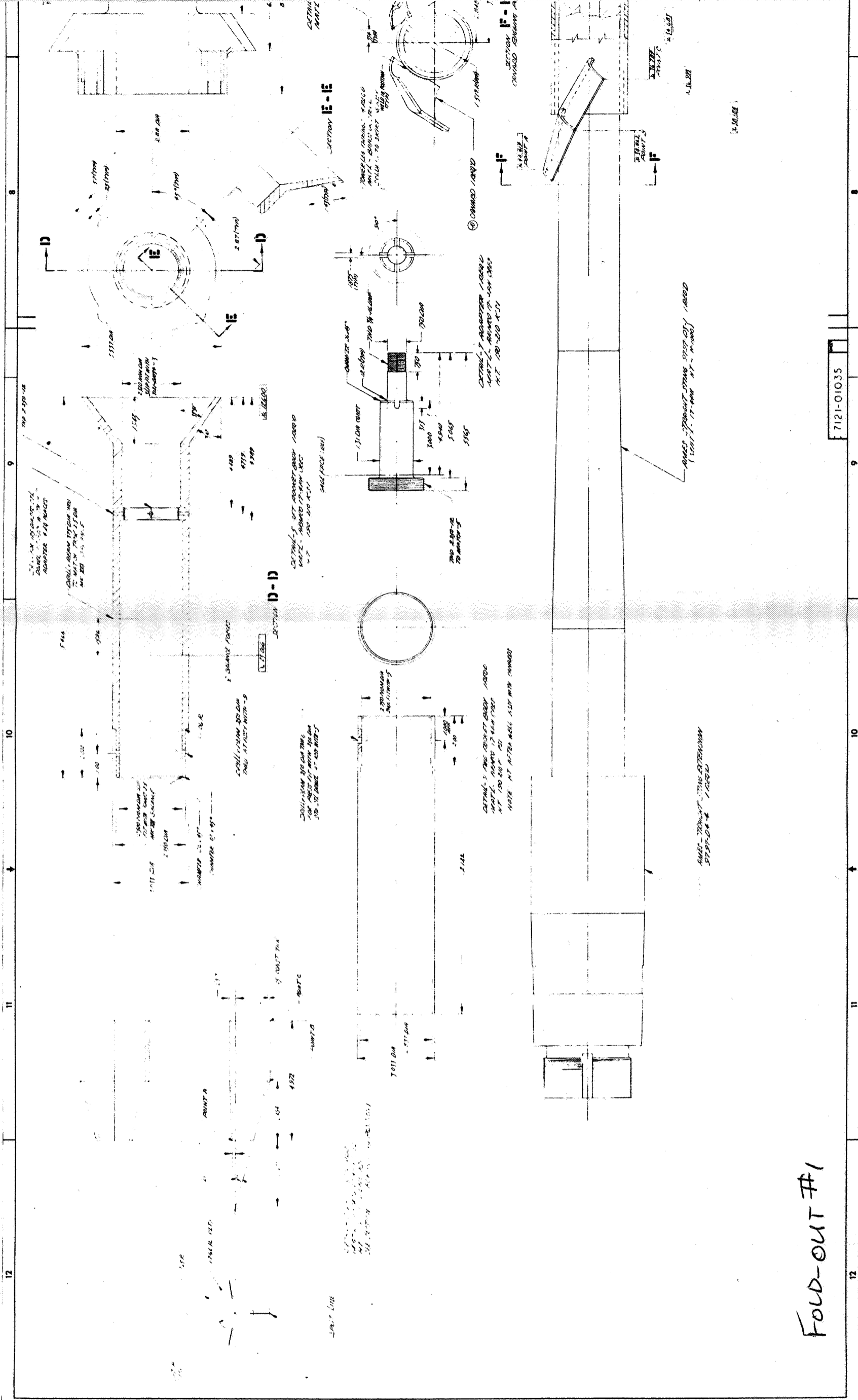


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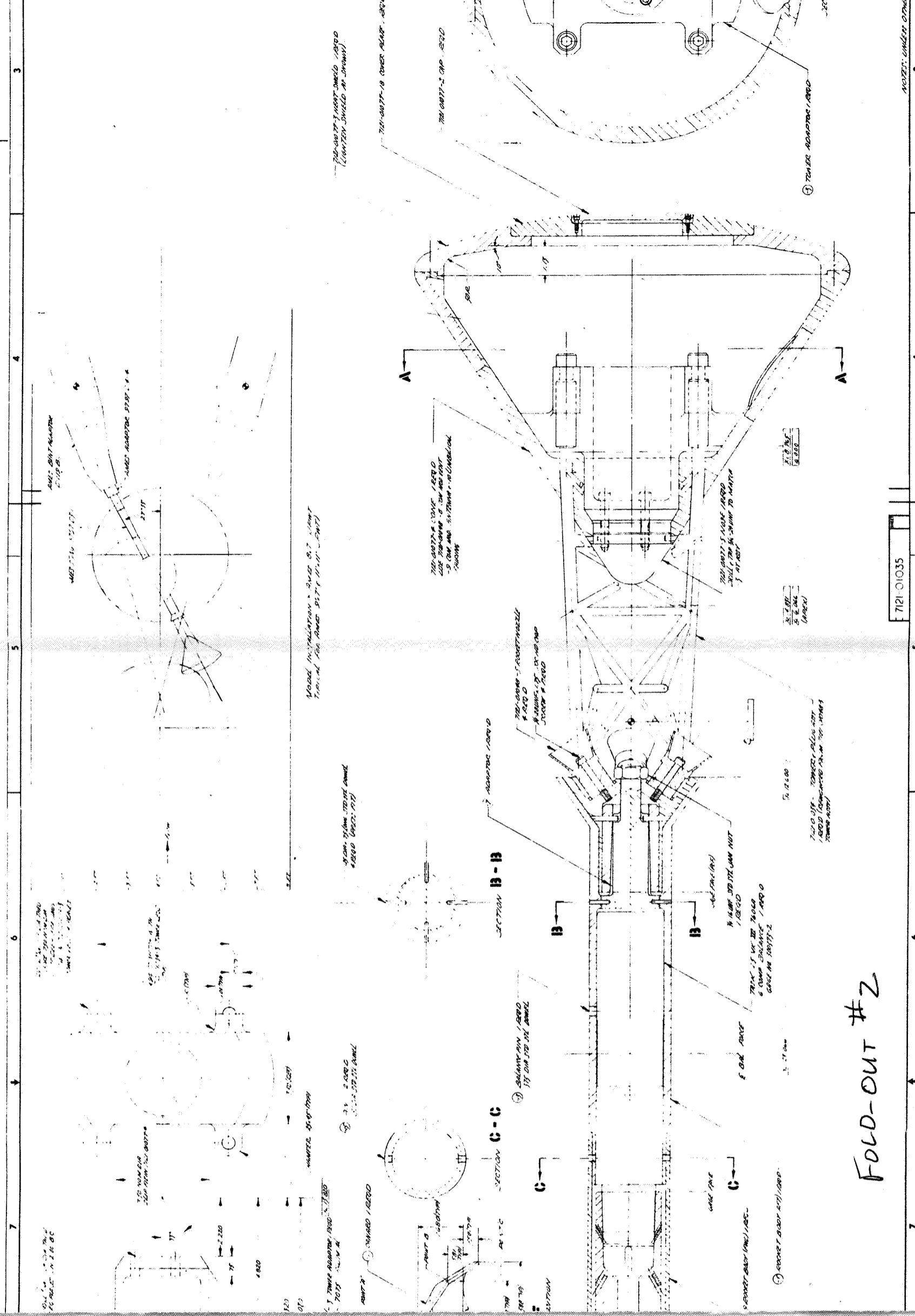
7121-01034

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ure 8. FS-2 Canard - Component Force Model (Ames UPWT June 1964)



FOLD-OUT #1



FOLD-OUT #2

Figure 9.

[illegible]



II. INSTRUMENTATION

FORCE MEASUREMENTS

Six-component force data on the Apollo FS-2 model will be measured using the Ames Task Mark XVI T 2.5 balance (1200 pound side force elements, 2400 pound normal force elements and 1500 pound axial force elements) and the Ames Task Mark II T 1.5 balance (250 pound side force elements, 500 pound normal force elements and 300 pound axial force elements). The dimensions for locating the balance in the various model cavities and moment transfer distances are presented in Section IV of this report.

It is requested that instrumentation be set up to provide maximum possible data accuracy.

PRESSURE MEASUREMENTS

Base pressure is to be measured with one pressure tube inserted in the aft end of the model sting cavity.



III. OPERATIONS

INSTALLATION

Dual Balance

The command module should be installed using the Ames Task Mark XVI T 2.5 balance Ames sting, and Ames adapter (reference drawing 7121-01034, Page 10). The Task Mark XI will be used as back-up balance.

The escape motor should be installed using the Ames Task Mark II T 1.5 balance supported by the tower and command module (reference drawing 7121-01034, Page 10).

Heat Shield Forward

The post-abort canard configuration heat shield model should be installed using the Ames Task Mark XVI T 2.5 balance (reference drawing 7121-01035, Page 11).

BALANCE CALIBRATION

It is requested that a check calibration be made in the tunnel, using the balance calibration body.

OPERATING CONDITIONS

These tests will be conducted at a tunnel dynamic pressure (q) of 540 psf for Mach numbers 0.5 to 3.0 and $q = 425$ psf for Mach number 3.4. Because of power limitations it is not possible to maintain $q = 540$ psf at Mach = 3.4. Squares with X in the run schedule indicate test points. (See Tables 1, 2, and 3).

ANGLE-OF-ATTACK SCHEDULE

The angle-of-attack schedule for the post-abort canard configurations is as follows:



Schedule	Strut Angle and Angle of Attack (Degrees)
A	Strut -15, -10, -7, -5, -3, -2, -1, 0, +1, +2, +3, +5, +7, +10, +15 $\alpha = \theta + \text{strut angle}$
B	Strut -15, -10, -5, 0, +5, +10, +15 $\alpha = \theta + \text{strut angle}$
C	Strut -15, -12.5, -7.5, -2.5, +2.5, +7.5, +12.6, +15 $\alpha = 192^{\circ}33' + \text{strut angle}$
D	Strut -15, -12.5, -7.5, -2.5, +2.5, +7.5, +12.5, +15 $\alpha = 167^{\circ}33' + \text{strut angle}$

PHOTOGRAPHIC REQUIREMENTS

Photographs showing the installation of the model in each of the three tunnels should be taken. In addition, the following significant model installation details should be photographed.

1. Close-up of the tower mounted balance installation.
2. Close-up of the attachment of tower leg supports inside command module for both test configurations.
3. Close-up of the attachment of the post-abort canard heat shield forward model configuration.

Schlieren photographs will be required at specific test points during testing in the three tunnels.



Table 1. Test Configuration and Run Schedule—Ames 11- by 11-Foot UPWT

Purpose of Test	Model Configuration	Mach Number					Model θ (deg)	Angle-of-Attack Range	Canard Roll Angle ϕ (deg)	Remarks
		0.70	0.90	1.10	1.20	1.35				
Static stability of post-abort canard configuration	C43V5T32E71	X	X	X	X	X	0	A	0	Two balance system
	↑	X	X	X	X	X	40	B	↑	↑
		X	X	X	X	X	60	↑		
		X	X	X	X	X	80			
		X	X	X	X	X	120			
		X	X	X	X	X	140			
		X	X	X	X	X	-40			
		X	X	X	X	X	-80	↑		
	↑	X	X	X	X	X	-120		↑	↑
	C43V5T32E71	X	X	X	X	X	-140	B	0	Two balance system
Static stability of post-abort canard configuration	C43V5T32E71	X	X	X	X	X	0	A	30	Two balance system
	↑	X	X	X	X	X	40	B	↑	↑
		X	X	X	X	X	80	↑		
		X	X	X	X	X	120			
	↑	X	X	X	X	X	140		↑	↑
	C43V5T32E71	X	X	X	X	X	-80	B	30	Two balance system
Static stability of post-abort canard configuration	C43V5T32E71	X	X	X	X	X	0	A	60	Two balance system
	↑	X	X	X	X	X	40	B	↑	↑
		X	X	X	X	X	80	↑		
		X	X	X	X	X	120			
	↑	X	X	X	X	X	140		↑	↑
	C43V5T32E71	X	X	X	X	X	-80	B	60	Two balance system
Static stability of post-abort canard configuration	C43V5T32E72	X	X	X	X	X	180	D	0	-12°33' sting
	C43V5T32E72	X	X	X	X	X	180	C	0	+12°33' sting



Table 2. Test Configuration and Run Schedule—Ames 9- by 7-Foot UPWT

Purpose of Test	Model Configuration	Mach Number			Model θ (deg)	Angle-of-Attack Range	Canard Roll Angle ϕ (deg)	Remarks
		1.6	2.0	2.4				
Static stability of post-abort canard configuration	C43V5T32E71	X	X	X	0	A	0	Two balance system
		X	X	X	40	B		
		X	X	X	60			
		X	X	X	80			
		X	X	X	120			
		X	X	X	140			
		X	X	X	-40			
		X	X	X	-80			
		X	X	X	-120			
		X	X	X	-140	B	0	Two balance system
Static stability of post-abort canard configuration	C43V5T32E71	X	X	X	0	A	30	Two balance system
		X	X	X	40	B		
		X	X	X	80			
		X	X	X	120			
		X	X	X	140			
		X	X	X	-80	B		
		X	X	X				
		X	X	X				
		X	X	X				
		X	X	X				
Static stability of post-abort canard configuration	C43V5T32E71	X	X	X	0	A	60	Two balance system
		X	X	X	40	B		
		X	X	X	80			
		X	X	X	120			
		X	X	X	140			
		X	X	X	-80	B		
		X	X	X				
		X	X	X				
		X	X	X				
		X	X	X				
Static stability of post-abort canard configuration	C43V5T32E72	X	X	X	180	D	0	-12°33' sting
	C43V5T32E72	X	X	X	180	C	0	+12°33' sting



Table 3. Test Configuration and Run Schedule—Ames 8- by 7-Foot UPWT

Purpose of Test	Model Configuration	Mach Number			Model θ (deg)	Angle-of-Attack Range	Canard Roll Angle ϕ (deg)	Remarks
		2.6	3.0	3.4				
Static stability of post-abort canard configuration	C ₄₃ V ₅ T ₃₂ E ₇₁	X	X	X	0	A	0	Two balance system
		X	X	X	40	B		
		X	X	X	60			
		X	X	X	80			
		X	X	X	120			
		X	X	X	140			
		X	X	X	-40			
		X	X	X	-80			
		X	X	X	-120			
	C ₄₃ V ₅ T ₃₂ E ₇₁	X	X	X	-140	B	0	Two balance system
Static stability of post-abort canard configuration	C ₄₃ V ₅ T ₃₂ E ₇₁	X	X	X	0	A	30	Two balance system
		X	X	X	40			
		X	X	X	80			
		X	X	X	120			
		X	X	X	140			
	C ₄₃ V ₅ T ₃₂ E ₇₁	X	X	X	-80	B	30	Two balance system
		X	X	X				
		X	X	X				
		X	X	X				
	C ₄₃ V ₅ T ₃₂ E ₇₁	X	X	X				
Static stability of post-abort canard configuration	C ₄₃ V ₅ T ₃₂ E ₇₁	X	X	X	0	A	60	Two balance system
		X	X	X	40	B		
		X	X	X	80			
		X	X	X	120			
		X	X	X	140			
	C ₄₃ V ₅ T ₃₂ E ₇₁	X	X	X	-80	B	60	Two balance system
		X	X	X				
		X	X	X				
		X	X	X				
	C ₄₃ V ₅ T ₃₂ E ₇₁	X	X	X				
Static stability of post-abort canard configuration	C ₄₃ V ₅ T ₃₂ E ₇₁	X	X	X	180	D	0	-12°33' sting
	C ₄₃ V ₅ T ₃₂ E ₇₁	X	X	X	180	C	0	+12°33' sting



IV, DATA REDUCTION

REQUIREMENTS

Data reduction programs should be set up to provide all standard aerodynamic force and moment coefficient data about the body (apex) and the stability (c.g.) axis for the dual balance canard configuration and the heat shield forward canard configuration.

The center of pressure location should be reduced to coefficient form, X_{cp}/D . Base pressure is desired in coefficient form $\Delta P/q$ and the lift-to-drag ratio, L/D , is required.

EQUATIONS AND METHODS

The aerodynamic force and moment coefficient data about body and stability axis of the post-abort canard configurations should be obtained by using the standard Ames data reduction equations for tests conducted in the unitary plan wind tunnel. Equations for the escape motor coefficients of the dual balance test program are presented below.

$$C_{A_{rocket}} = C_{A_{balance}}$$

$$C_{N_{rocket}} = C_{N_{Frocket}} + C_{N_{Arocket}} = C_{N_{rocket}}$$

$$C_{m_{Arocket}} = 21.340 C_{N_{rocket}} + C_{m_{balance}}$$

$$C_{m_{cg}} = 2.3991 C_{N_{rocket}} + C_{A_{rocket}} \bar{Z} + C_{m_{Arocket}}$$

$$(X_{cp})/D = C_{m_{Arocket}} / C_{N_{rocket}}$$

Data Reduction Factors

- | | |
|---|---|
| S | Reference area (maximum cross section command module)
1.4261 Ft ² |
| D | Reference length (maximum diameter command module)
1.3475 ft |

Post Abort Canard Configuration

- \bar{X} Longitudinal distance from command module apex to center of gravity measured parallel to model center; negative when c.g. is aft (toward heatshield) of apex, -2.6513 inches
- \bar{Z} Vertical distance from model axis to center of gravity; positive below model axis, +0.5985 inches.

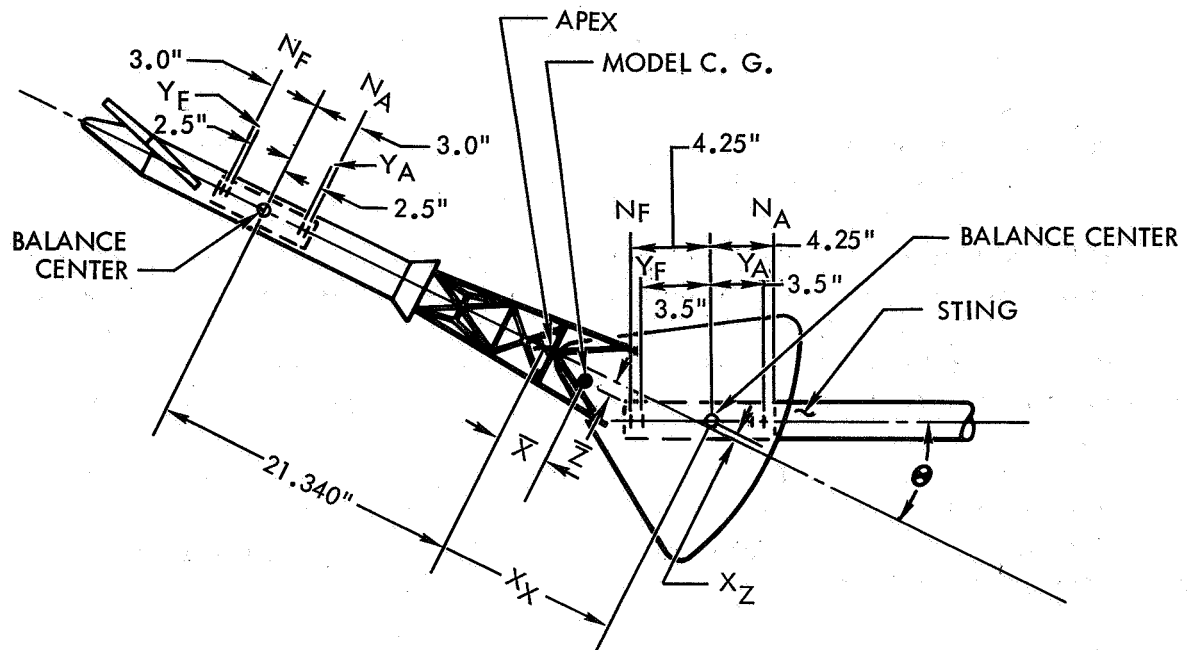
Moment Transfer Dimensions

Moment transfer distances from the command module apex to the balance center have been tabulated below. Figure 10 defines moment transfer dimensions.

θ (Deg)	X_x (In.)	Z_z (In.)
0	-8.7648	0.0000
20	-9.4944	-1.0164
40	-9.7284	-0.9924
60	-10.2444	-1.2516
80	-9.8976	-0.8064
100	-9.7680	0.0624
120	-9.8088	0.4968
140	-9.1752	0.5280



DUAL BALANCE INSTALLATION



HEAT SHIELD FORWARD BALANCE INSTALLATION

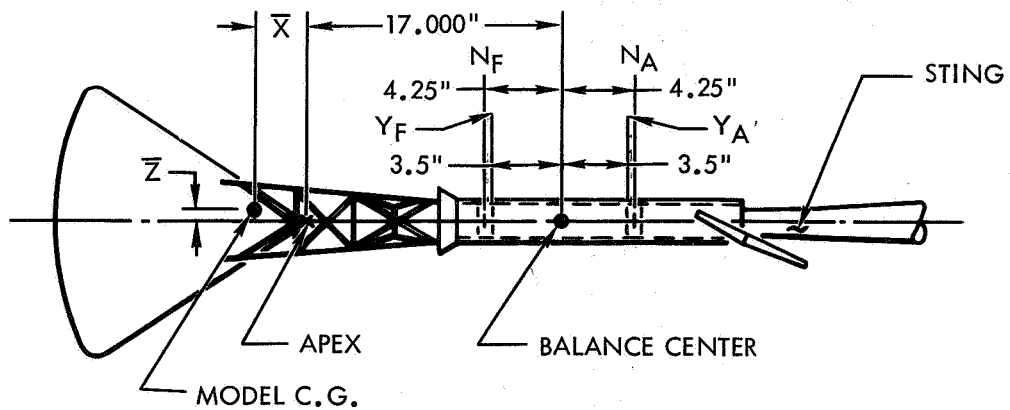


Figure 10. Post-Abort Canard Configuration Moment Transfer Definitions



V. DATA PRESENTATION

During testing in unitary plan wind tunnels, a copy of unchecked tabulated data (flexowriter) will be required.

S&ID has a contractual obligation to provide NASA MSC with a preliminary report containing tabulated data 30 days after the completion of each test. To meet this requirement, it will be necessary to have a complete set of tabulated data in reproducible form not later than 10 working days after the test. A copy of the tunnel log should also be provided.

In addition to the tabulated data, it is desired that one set of IBM cards containing tabulated data be sent to S&ID at the same time. These data contained in the IBM cards will be used to prepare plot cards for obtaining plotted data.

Distribution of this data is to be as follows:

1. Letter of transmittal, two copies of the tabulated data including tunnel run log, and one set of IBM cards to:

North American Aviation, Inc.
Space and Information Systems Division
12214 Lakewood Boulevard
Downey, California
Attention: Mr. Edwin C. Allen, Dept. 696-714

Through:

NASA Apollo Program Office
North American Aviation
12214 Lakewood Boulevard
Downey, California
Attention: Mr. Robert H. Ridnour

2. Letter of transmittal and one copy of the tabulated data including tunnel run log to:

NASA Manned Spacecraft Center
Apollo Spacecraft Center
Houston, Texas
Attention: Mr. Calvin H. Perrine



3. Letter of transmittal and one copy of the tabulated data including tunnel run log to:

NASA Manned Spacecraft Center
Advanced Spacecraft Technology Division
Houston, Texas
Attention: Mr. W.C. Moseley, Jr.



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